Klozur® CR

KLOZUR™
Power. Stability. Versatility.

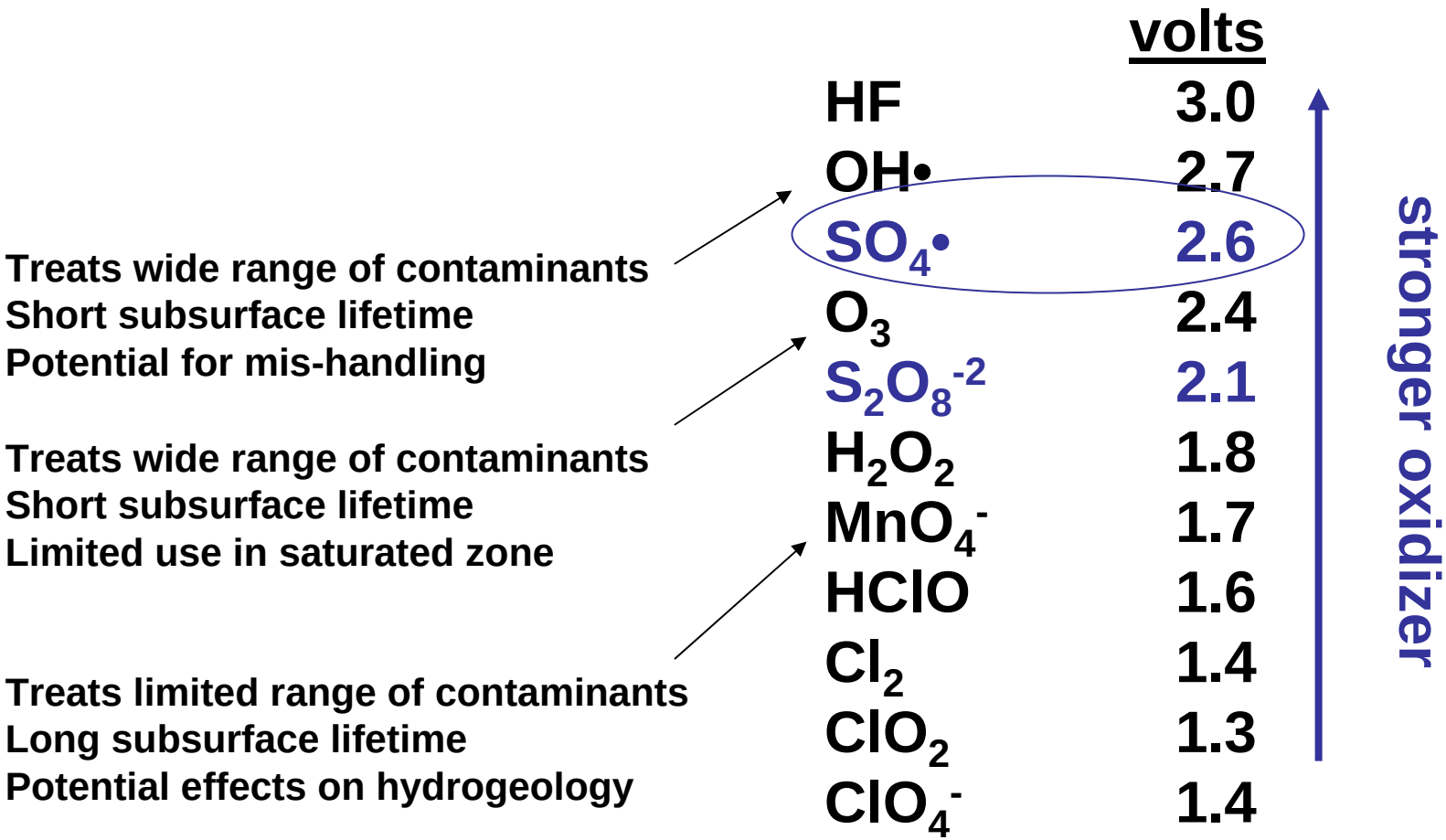
Combined Chemical and Bio-Remediation

Klozur® CR

A combination mixture that supports a two fold mechanism for treating contaminates of concern, short term In Situ Chemical Oxidation (ISCO), with alkaline activated Klozur® persulfate and an electron acceptors for longer term biological oxidation, via PermeOx™ Plus.

- One package treatment for ISCO and Bio-remediation
- Self activating system

Oxidation – Reduction Potentials of Various Chemistries



But, in general, direct oxidation by persulfate anion is *kinetically slow…..*

need to activate

Sulfate free radical:

$SO_4^{\bullet -} + e^- \rightarrow SO_4^{-2}$ $\quad E^0 = \sim 2.6$ v

- **very strong oxidizer and kinetically fast**
- **free radical chemistry is not necessarily straightforward or stoichiometric**

The key is how to activate persulfate for your contaminant and site conditions!

Klozur™ Persulfate Activation Chemistries

Conventional

- heat
- divalent metals (Fe^{+2})

FMC Klozur™ Chemistries (patent pending)

- chelated metals
- hydrogen peroxide activation
- Alkaline pH

One key to success: Proper activation for your contaminant and site lithology and hydrogeology

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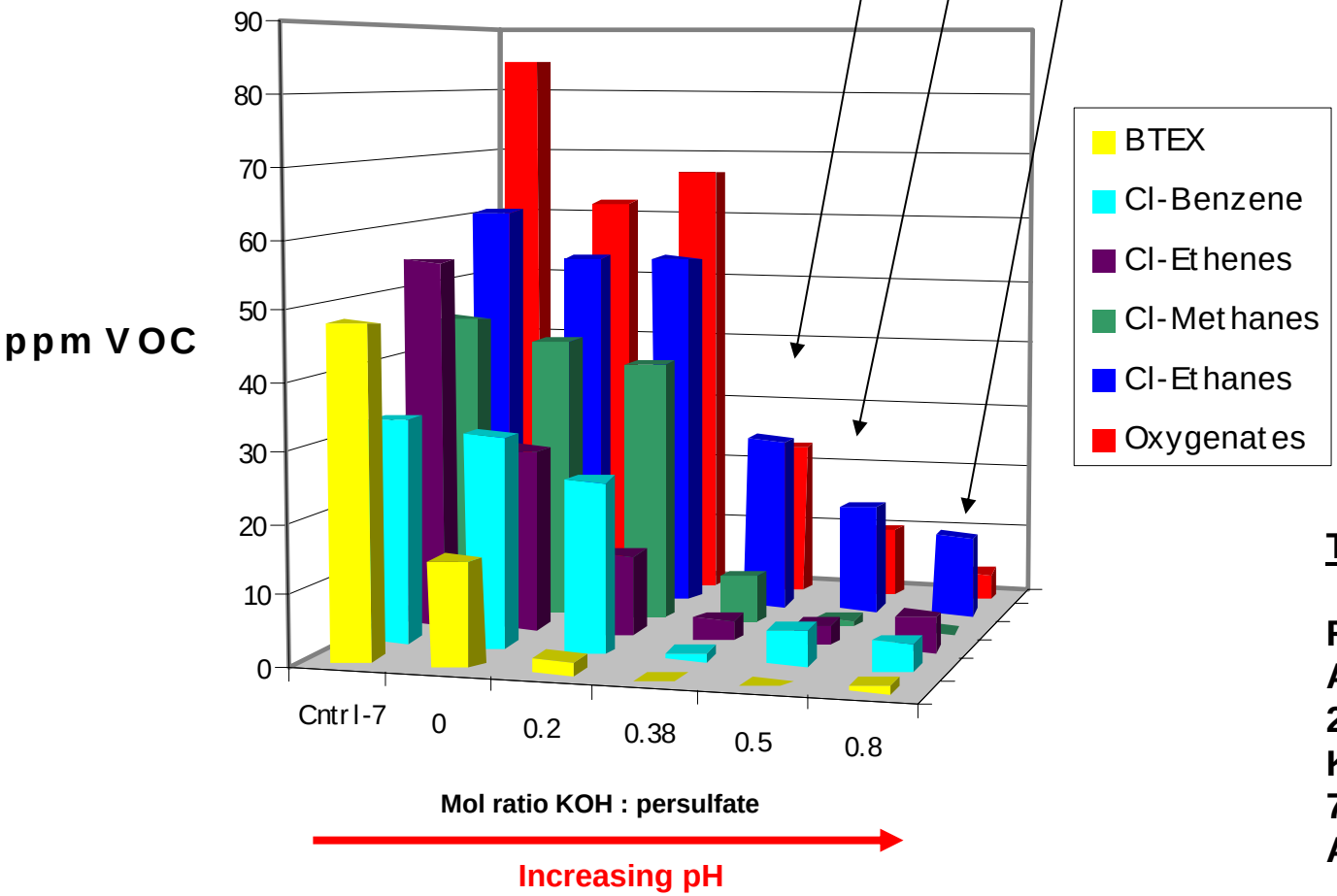
Klozur™ Activation Chemistries

Alkaline Activation

- pH > 10

pH 10, pH 1, pH12

Degradation of COC Utilizing Alkaline Activation



Treatability Study

Room temperature
Aqueous solutions
25 g/L sodium persulfate
KOH as pH modifier
7 days
Analyzed by GC-MS

PermeOx® Plus

Use:

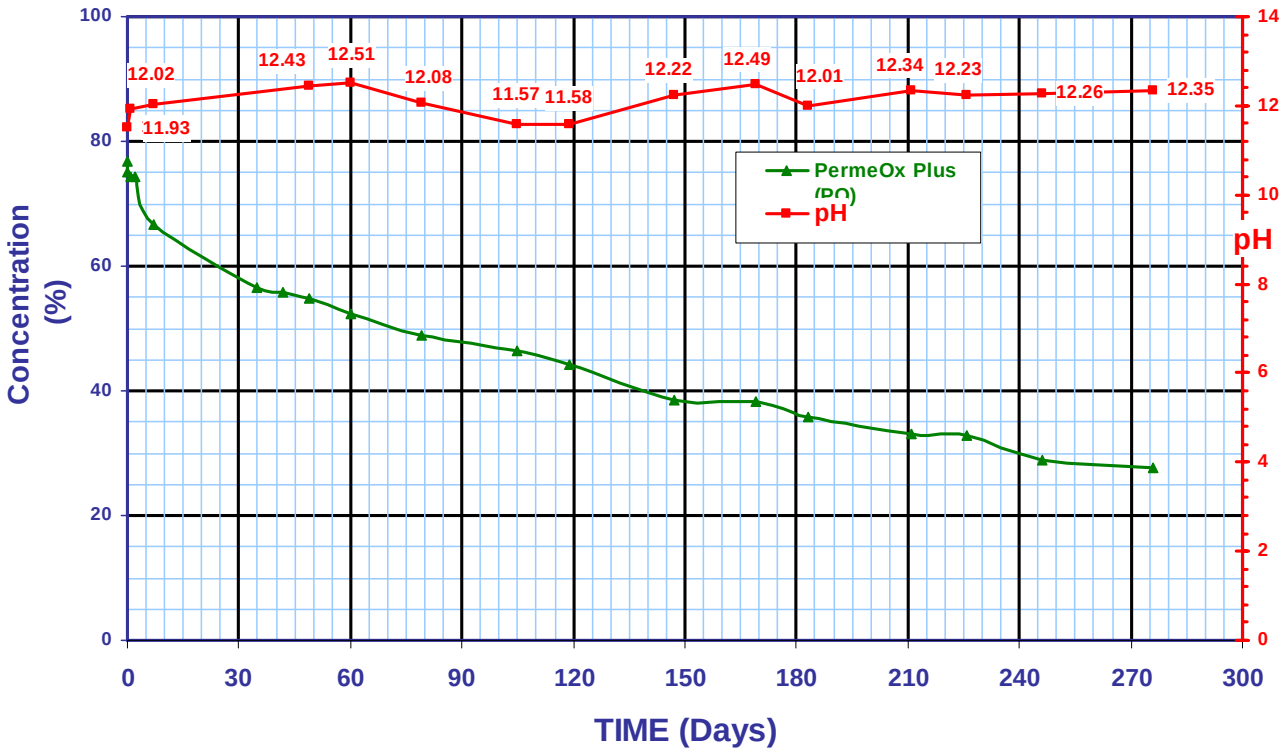
Bio-remediation of Chemicals of Concern
Natural Attenuation is often limited by the amount of oxygen available to the microbiological population

PermeOx® Plus provides slow release of oxygen for enhanced natural attenuation

Examples

- Petroleum Hydrocarbons Remediation
- Creosote Remediation

Fig. 1: Hydrolysis of PermeOx Plus in DI Water at 25°C



Chemistry

- Coupled Chemical Oxidation and Bioremediation
- $S_2O_8^{=}$ + Activator → $2SO_4$*-
- CaO_2 (engineered) + H_2O → $Ca(OH)_2$ + H_2O_2
- $2H_2O_2$ → O_2 + H_2O

Characteristics of Klozur CR

pH above 10 for life time of Klozur Persulfate

Sufficient Oxygen Release for more than 180 days

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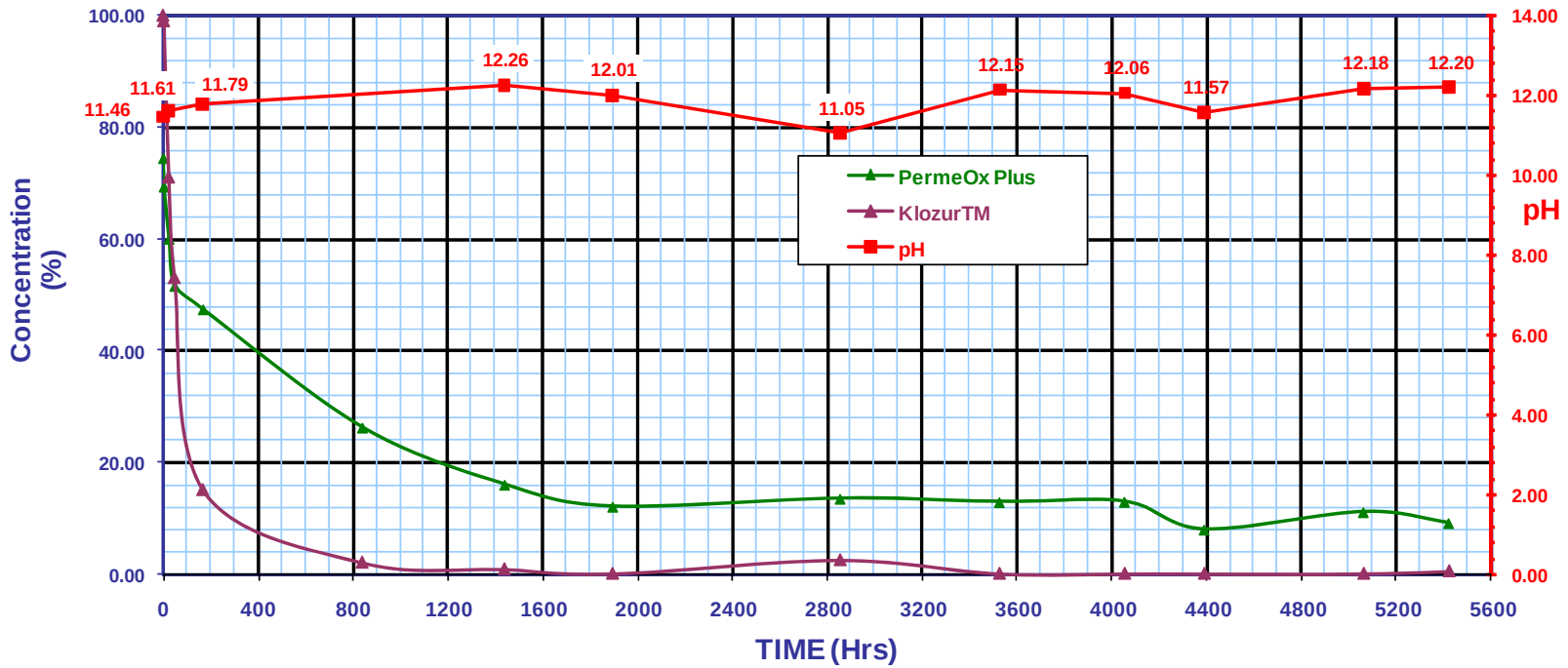
Fig. 4: Hydrolysis of PermeOx Plus/Klozur™ in DI Water at 25°C



Acknowledgement

FMC Environmental Solutions

- Innovative Coupled Chem-Bio Treatability Study leading to Large Scale Pilot Test at a Wood Treating Facility

- James Studer, Michael Lee, Ph.D, Jack Sheldon, Norm Kennel

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- Lab Study *
- 1225 Acre active wood treating facility in Mississippi
- Semi volatile organic compounds (SVOC)
  - Pentachlorophenol (PCP), Naphthalene, Anthracene Benzo(a)anthracene, Benzo(a)pyrene, Pyrene, et. al

- Geochemical data
- Thick sequence of alluvium
- Contaminant loading as high as 3400 mg/Kg TOC, 448 mg/Kg COD
- Soil/Groundwater
- pH 3.8 – 4.3
- ORP -38 to 24 mV

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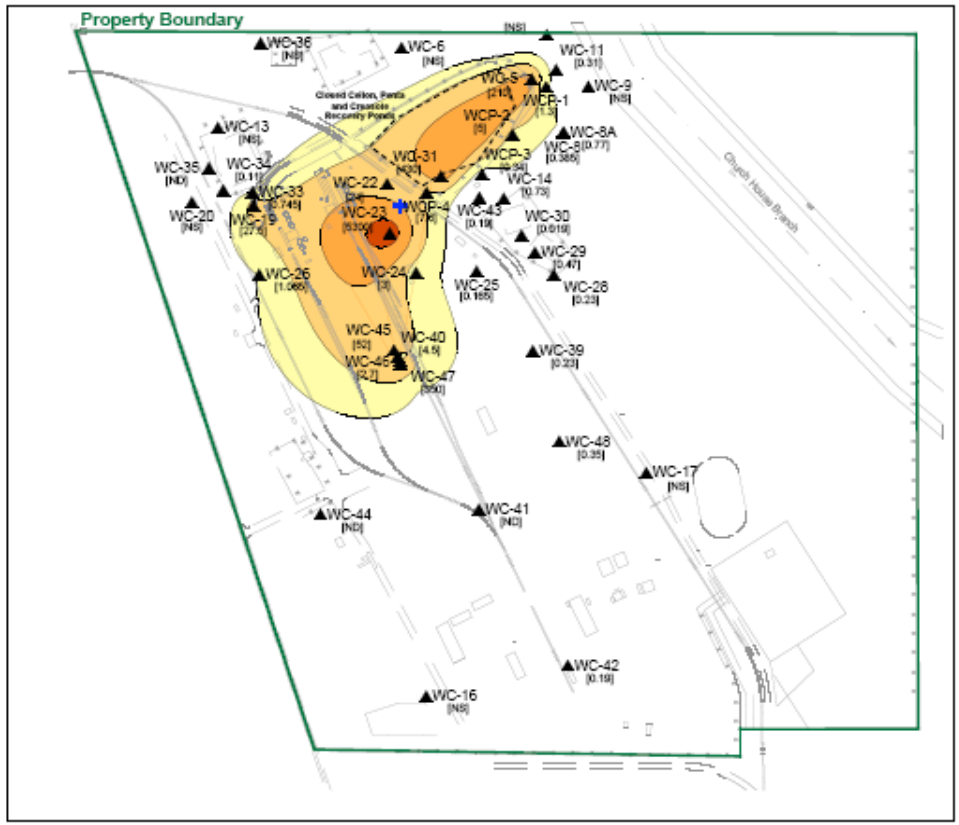
Figure 1. Site Plan – Active Operations Area with PCP Plume as of 2006



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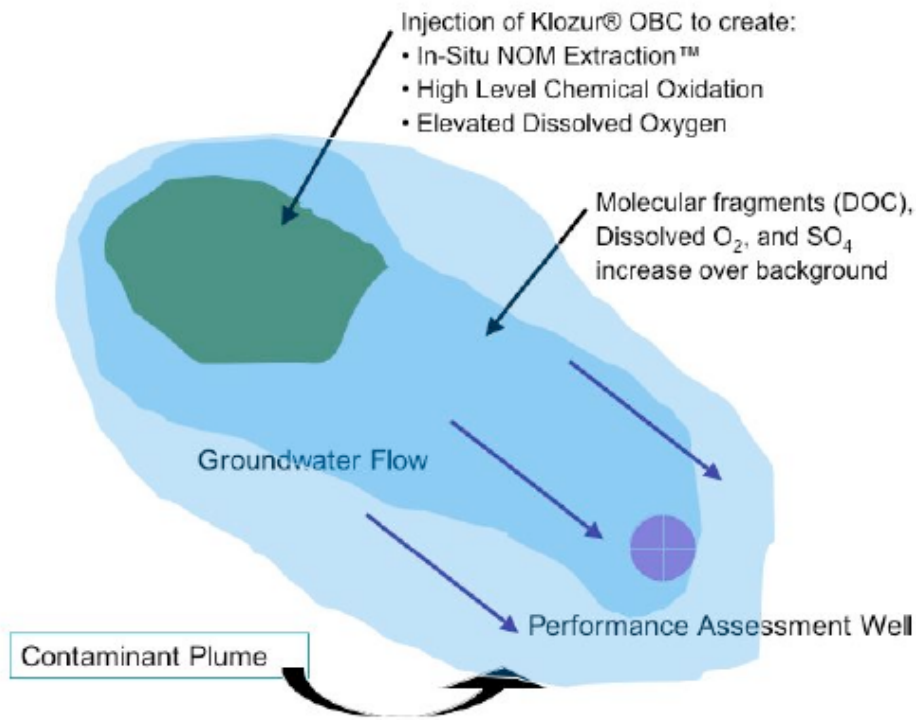
- Treatment Strategy
  - Coupled oxidative and bio-remediation
  - Hot spots WC 5 and WC23
  - Enhance bio treatment WC 40

  - Alkaline Activated Klozur Persulfate for rapid and complete chemical oxidation
  - Long term oxygen supply from PermeOx Plus to sustain aerobic biodegradation

Figure 3. Conceptualization of Coupled Chemical Oxidation - Oxidative Biodegradation



- Treatability Study Design
- Initial Conditions
  - Soil
  - 3400 mg/kg TOC 440 mg/kg COD
  - ORP -38 mv
  - pH 3.8
  - 1.5 PPM PCP, 120 PPM Naphthalene, 13 PPM Anthracene, 1.0 PPM Acenaphthylene, 8.6 PPM benzo(a)anthracene, 0.36 PPM 2,4 dimethylphenol, 37 PPM pyrene
  - Ground water
  - 46 mg/L COD
  - ORP 24 mV
  - pH 4.3
  - 4.9 PPM PCP, 0.6 PPM 2,4,6 trichlorophenol

- Destruction Removal Efficiency (DRE)
  - Long term test to investigate the effectiveness of Klozur CR to destroy soil and ground water contaminants

•Analyses performed on the following sample

		pH	ORP	DO
•Time 0	no treatment	4.3	257mV	8.6 mg/l
•Day 1	~20.2 g/kg	10.4	70 mV	8.3 mg/l
•Day 8	~3.23 g/kg	8.3 (adj pH 11)	163mV	9.5 mg/l
•Day 29	~3.23 g/kg	7.3 (adj pH 11)	182 mV	9.4 mg/l
•Day 64	~1.67 g/kg	8.8	124 mV	7.4 mg/l

- DRE Test
  - Initial Concentration (10-100 PPM)
    - Naphthalene, anthracene, pyrene benzo(a)anthracene
    - 64 day anthracene, non detect
    - Others > 50% reduction

- DRE Test
  - Initial Concentration (< 10 PPM)
    - PCP, benzo(a)pyrene
    - 64 day benzo(a)pyrene non detect
    - PCP non detect
    - All other reduced by > 50%

- ISCO is an effective method to destroy aromatic compound and chlorinate aromatic compounds

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- Biologicals
  - Initially $2.08X10^7$
    - Proteobacteria 48%
    - Firmicutes 26%
    - General bacteria 10.2%
    - Anaerobic bacteria remainder

-29 day results $2.2X10^6$

Anaerobes reduced as soil became more aerobic

General bacteria increased

>64 day $6.7X10^6$

Proteobacteria increased

•Conclusion

•No sterilization of the soil

•Slight reduction of microbial population that rebounded

•Change to more aerobic microbial population

•No organisms detected with slowed growth or reduced permeability

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- Preliminary Field Results (5 months)
- pH > 10
- Dissolved oxygen significantly increased
- ORP significantly increased
- COC’s reduced by as much as 50%